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Kamee et al.

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(45) Date of Patent: Aug. 23, 2016

(54) **LIGHT SOURCE DEVICE FOR TUBULAR OBSERVATION DEVICE**

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(22) Filed: **Jul. 16, 2014**

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(30) **Foreign Application Priority Data**

Jan. 23, 2012 (JP) 2012-010882

(51) **Int. Cl.**

F21V 5/00	(2015.01)
F21V 9/08	(2006.01)
G02B 23/26	(2006.01)
A61B 1/06	(2006.01)
F21V 13/08	(2006.01)

(52) **U.S. Cl.**

CPC ***F21V 9/08*** (2013.01); ***A61B 1/0684*** (2013.01); ***F21V 13/08*** (2013.01); ***G02B 23/26*** (2013.01)

(58) **Field of Classification Search**

CPC G02B 6/0026; G02B 27/142; G02B 6/4215; G02B 6/0003; G02B 2207/113

USPC 362/583

See application file for complete search history.

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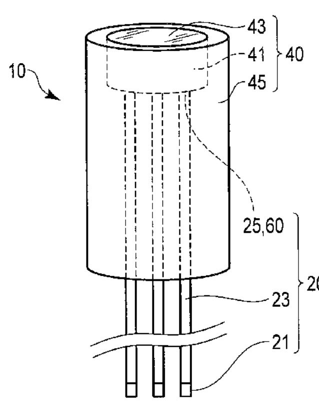
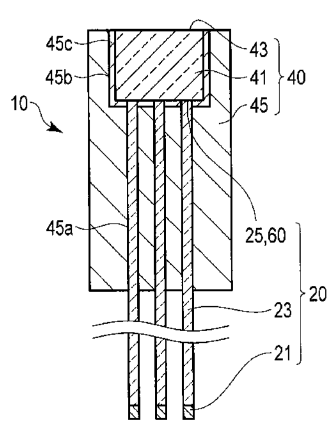
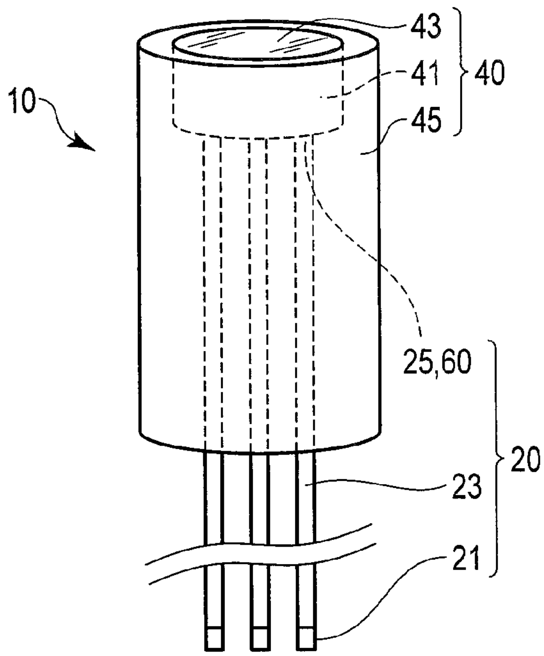
(57) **ABSTRACT**

A light source device includes a primary light source unit and a light converting unit. The primary light source unit includes a primary light emitting portion. The light converting unit includes a light converting member and a secondary light emitting portion. In the two-dimensional shape of the secondary light emitting portion projected on a surface perpendicular to the optical axis of primary light, the length of the minimum width of the two-dimensional shape passing through the center of gravity of the two-dimensional shape is different from the length of the maximum width of the two-dimensional shape passing through the center of gravity.

27 Claims, 16 Drawing Sheets







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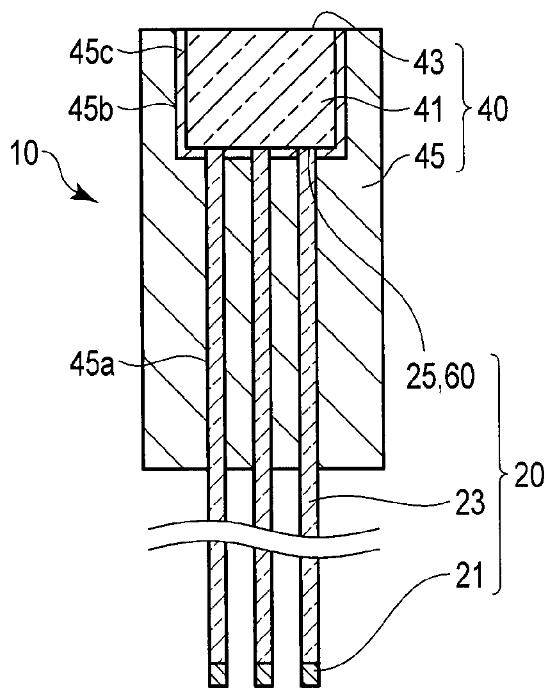

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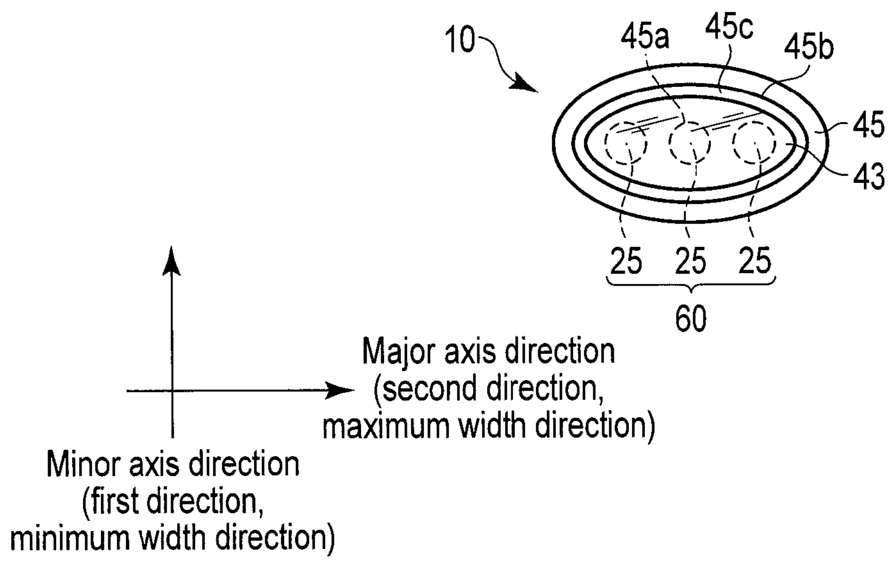
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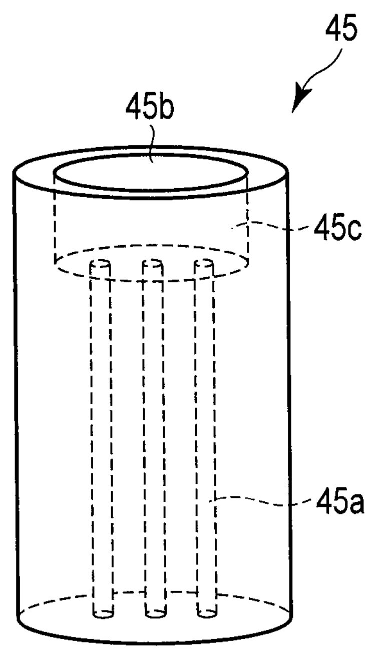
F I G. 1C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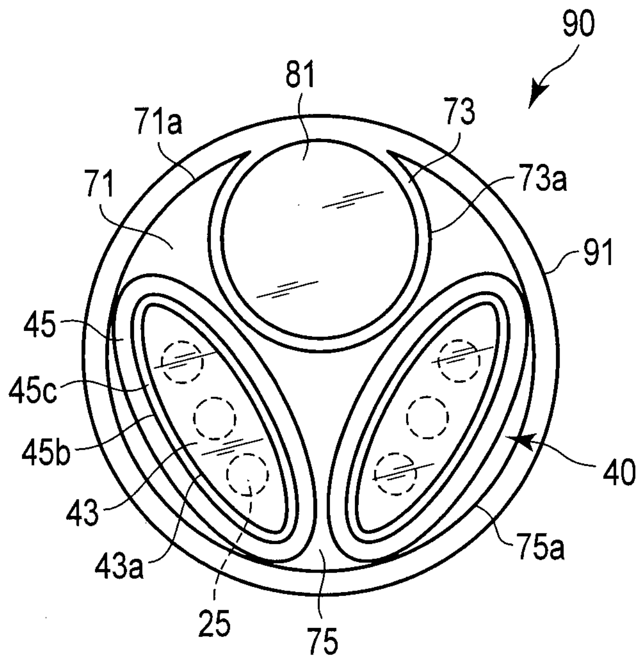
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FIG. 1E

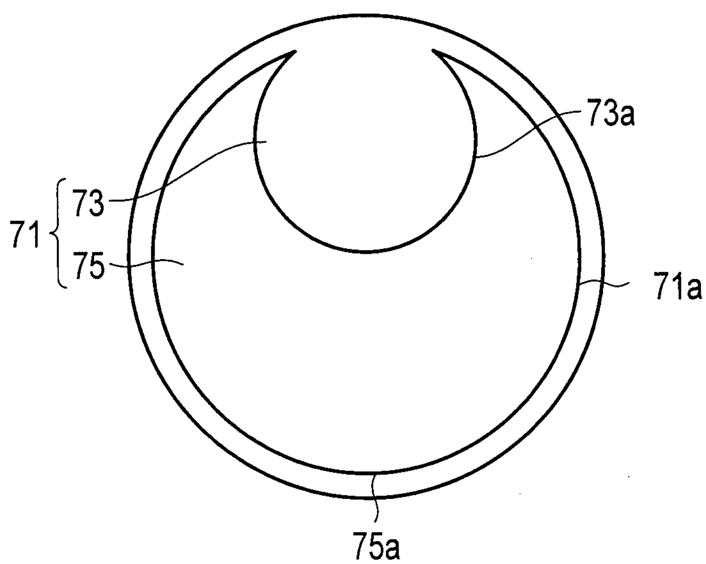
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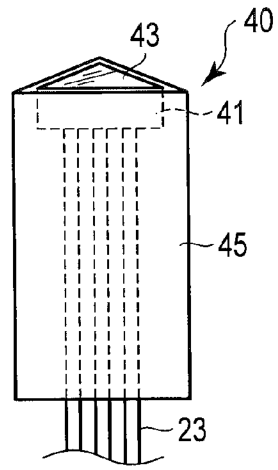
FIG. 1F



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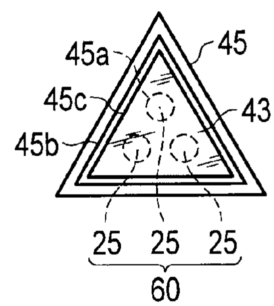

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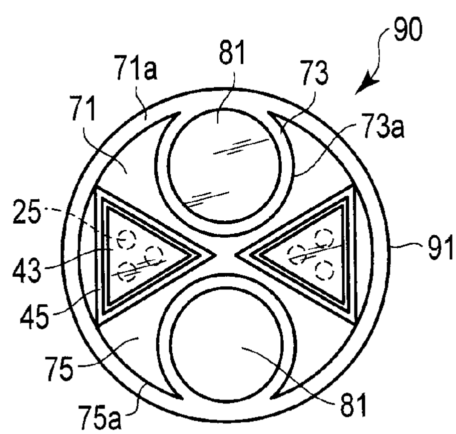

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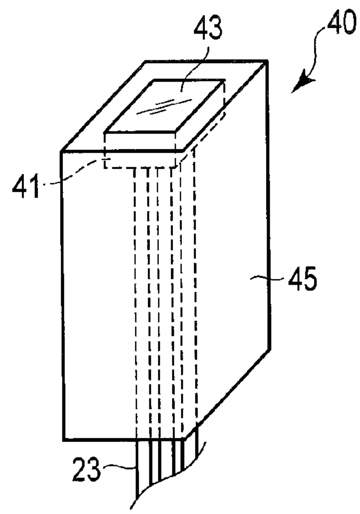

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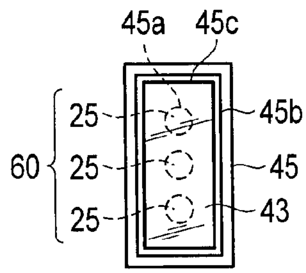

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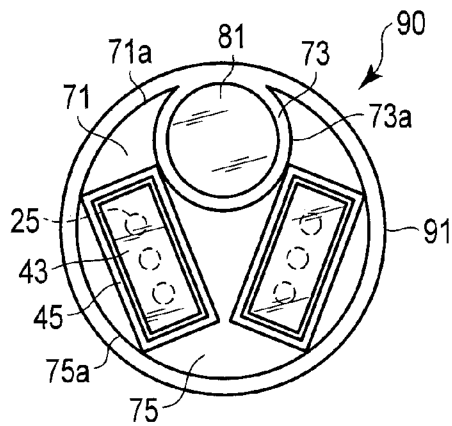

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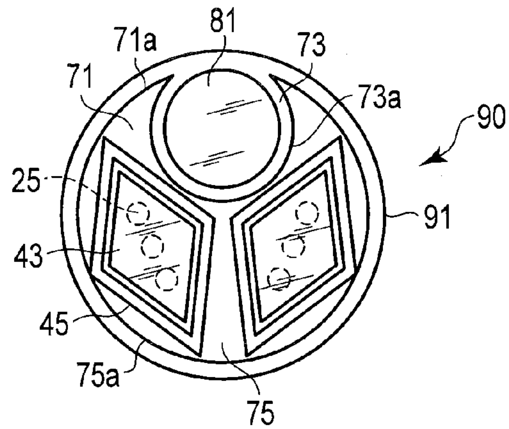

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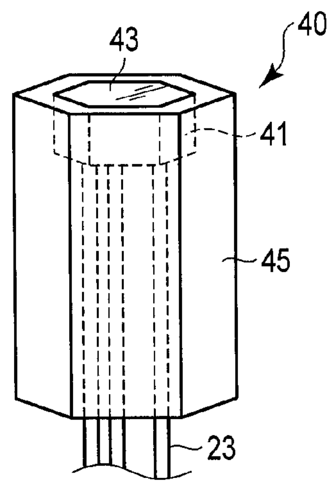

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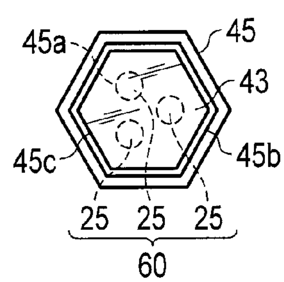

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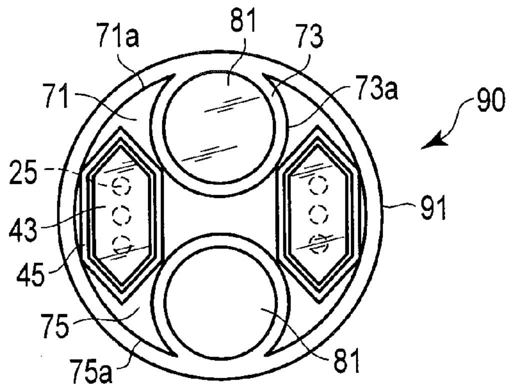

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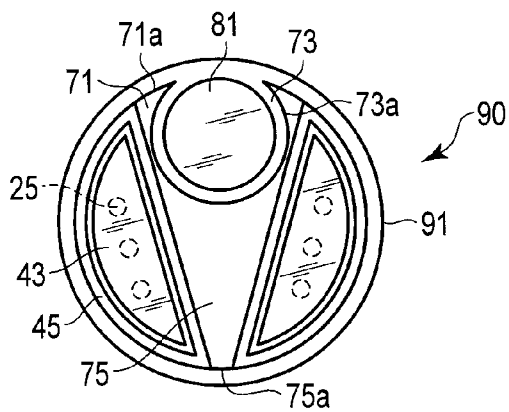

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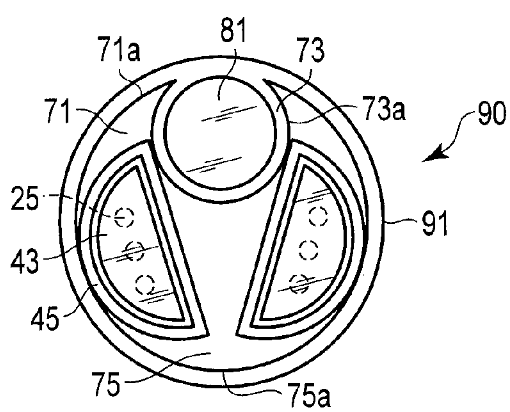

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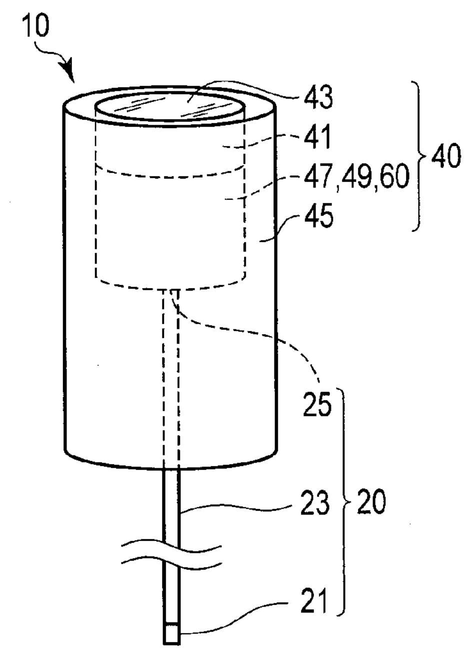
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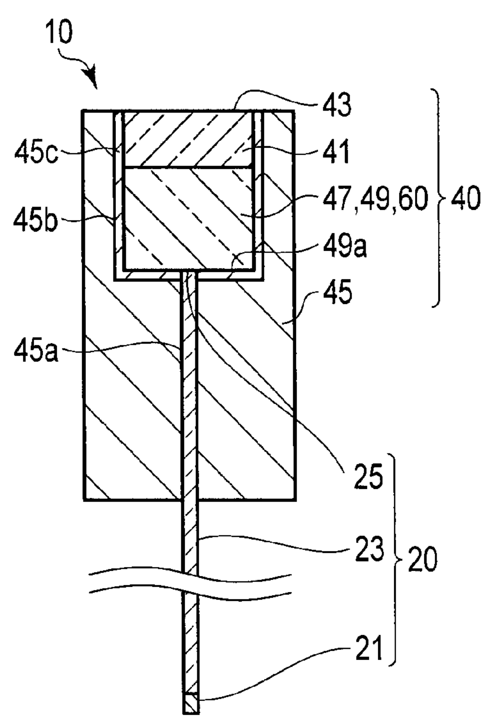
F I G. 3A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F I G. 3B

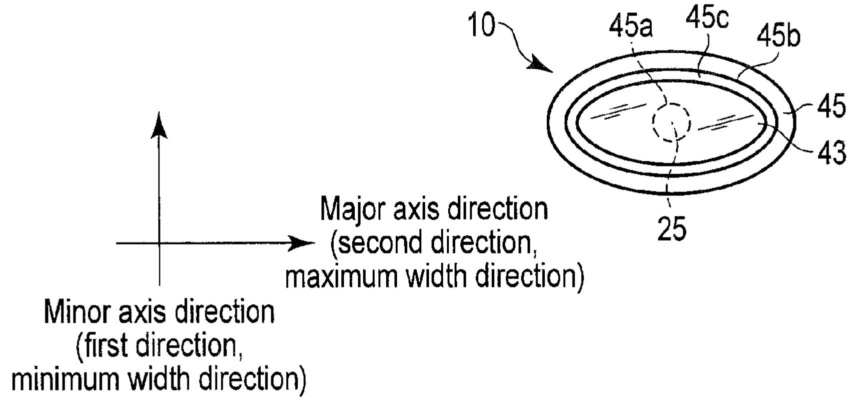

FIG. 3C

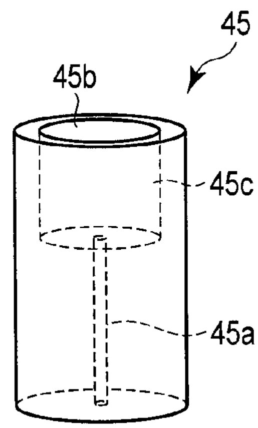

FIG. 3D

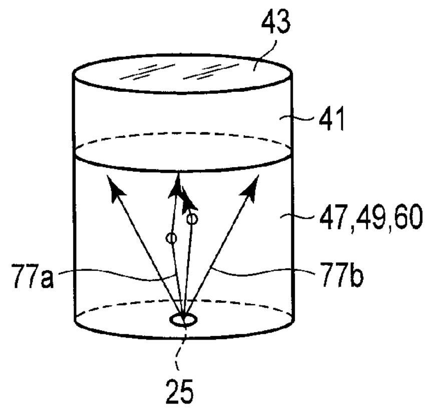

FIG. 3E

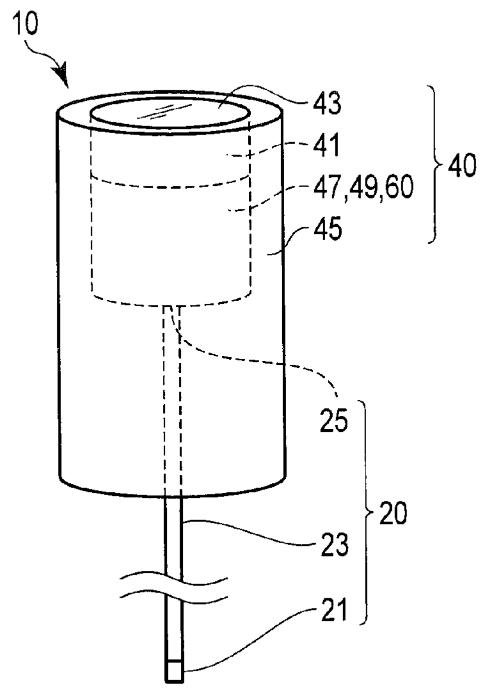
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FIG. 4A

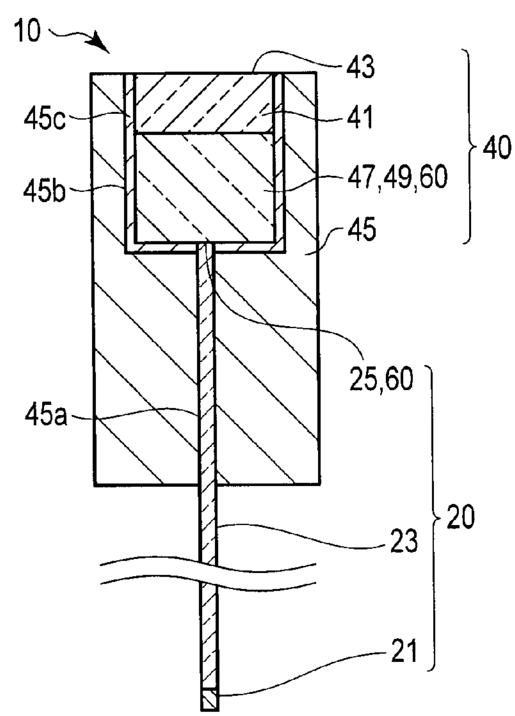
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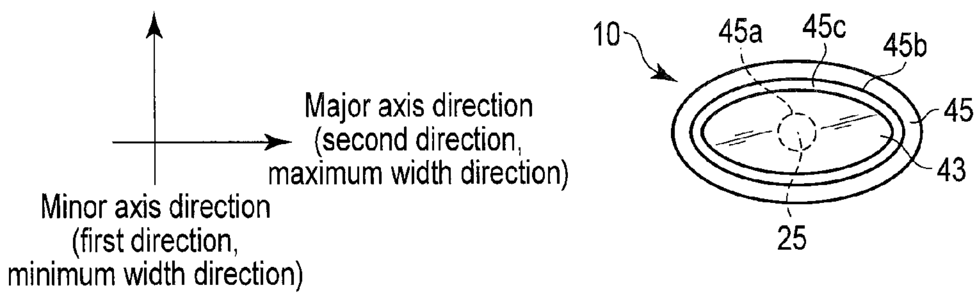
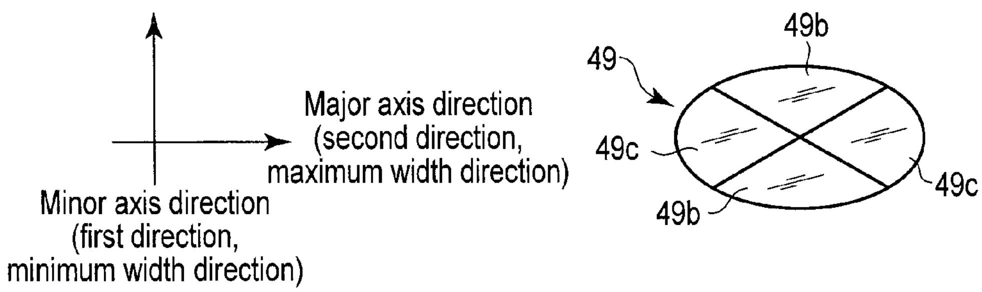
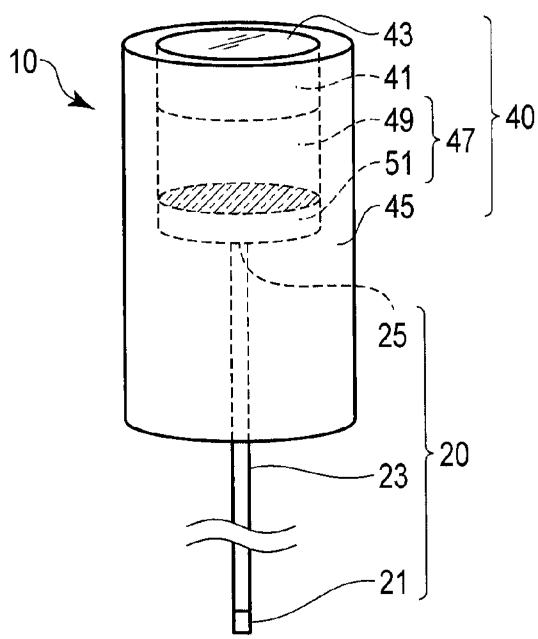
FIG. 4B



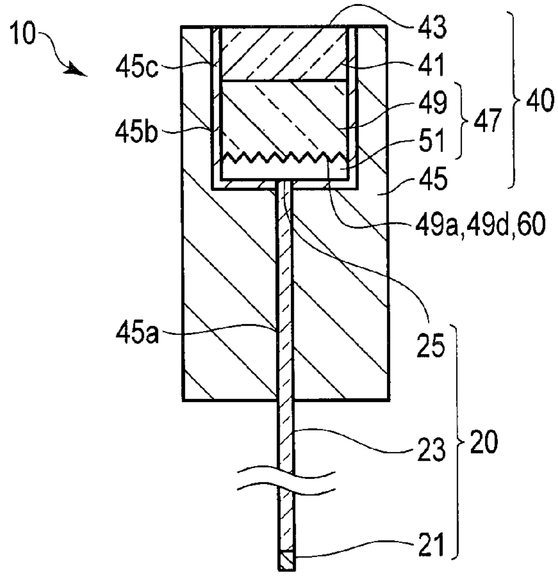
F I G. 4C



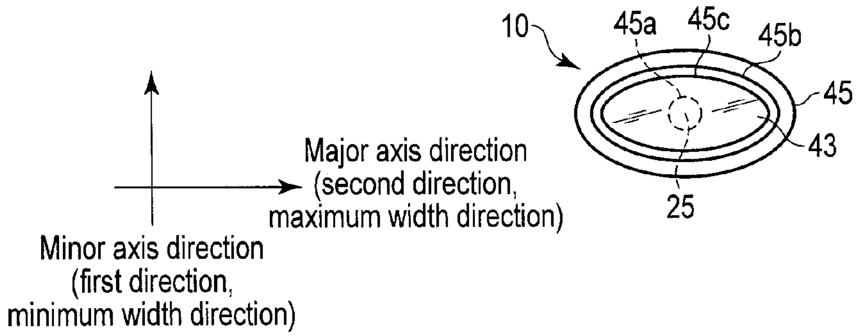
F I G. 4D



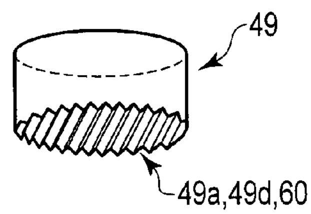
F I G. 5A



F I G. 5B



F I G. 5C



F I G. 5D

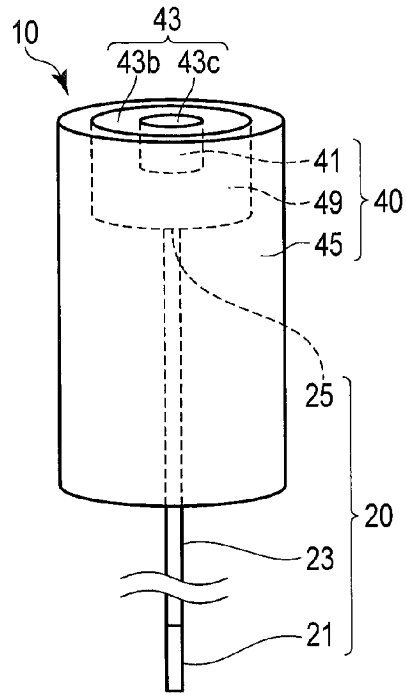

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FIG. 6A

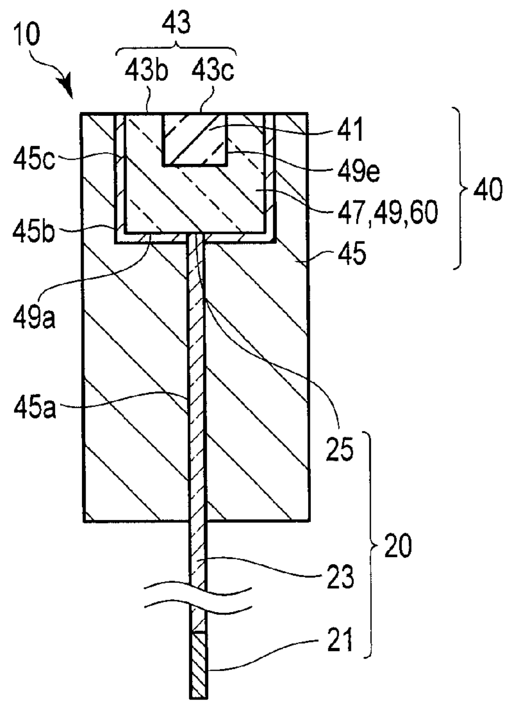
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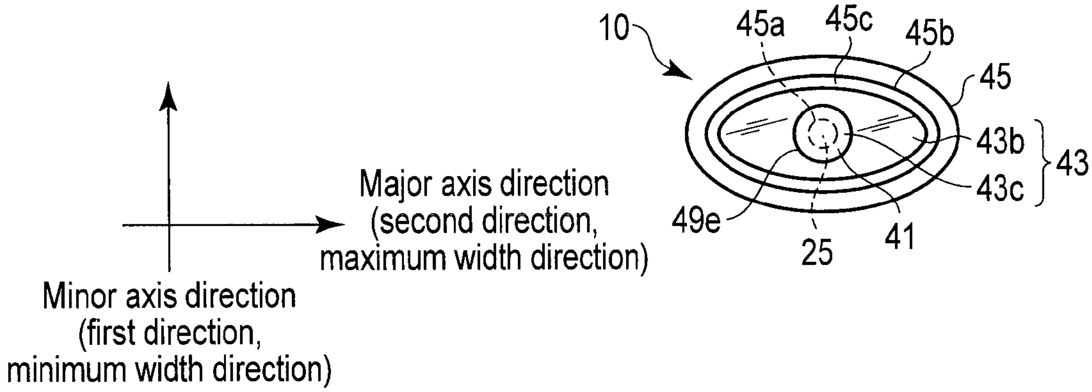
FIG. 6B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Major axis direction
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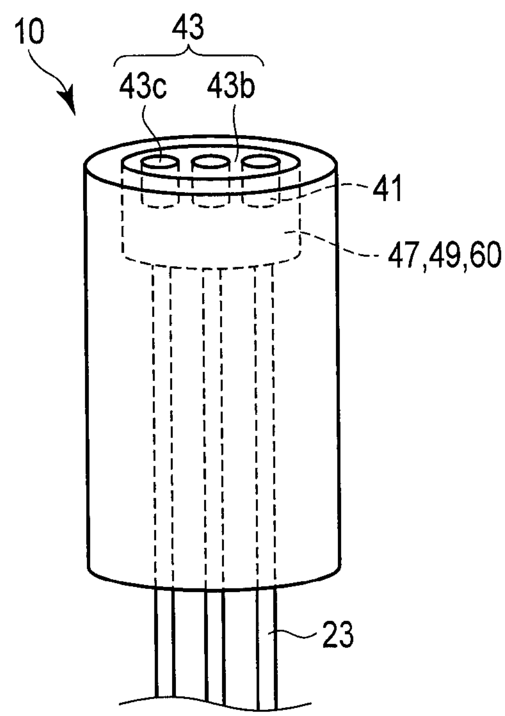
Minor axis direction
(first direction,
minimum width direction)

F I G. 6C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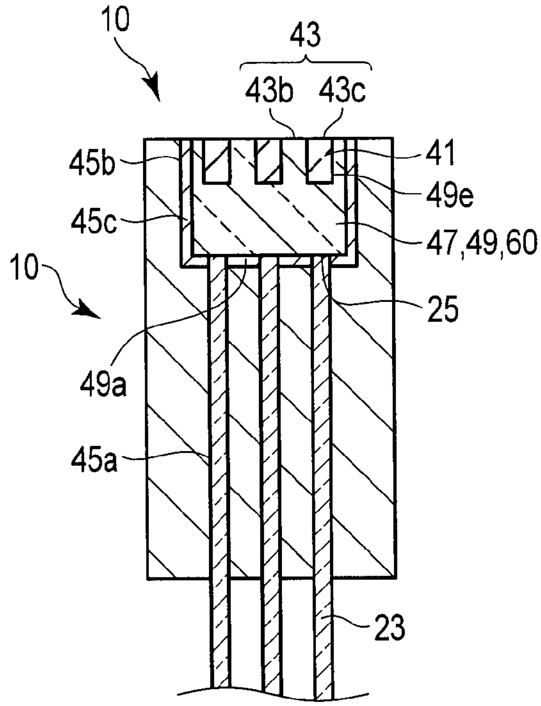
F I G. 6D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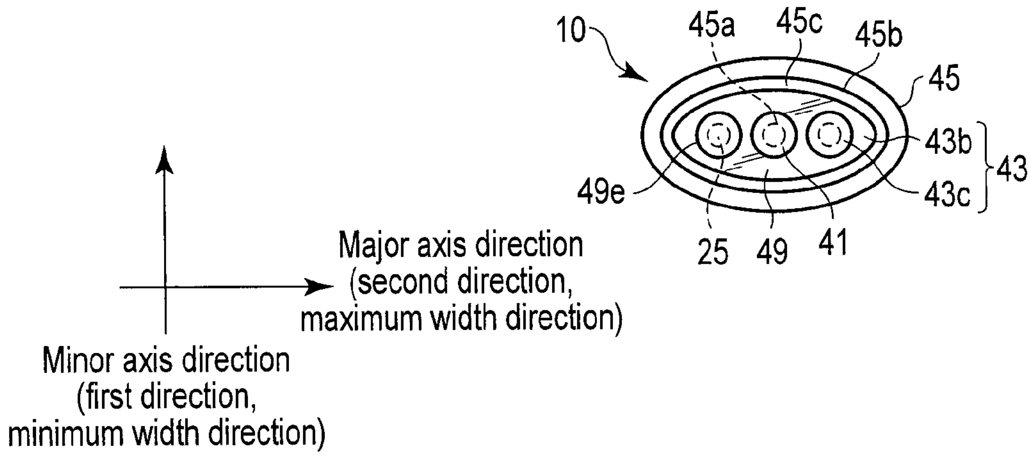
F I G. 6E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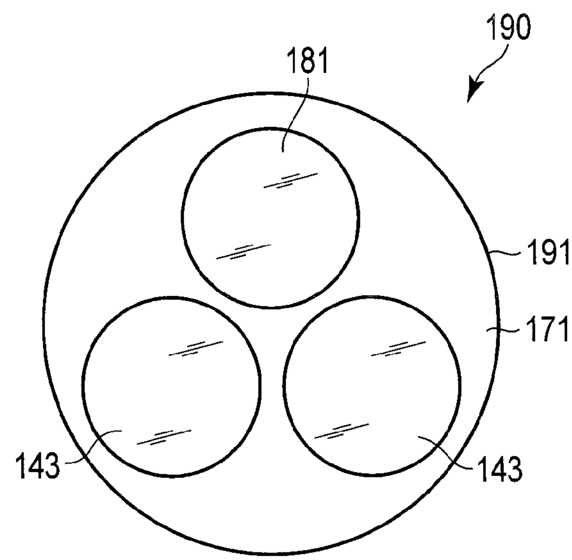
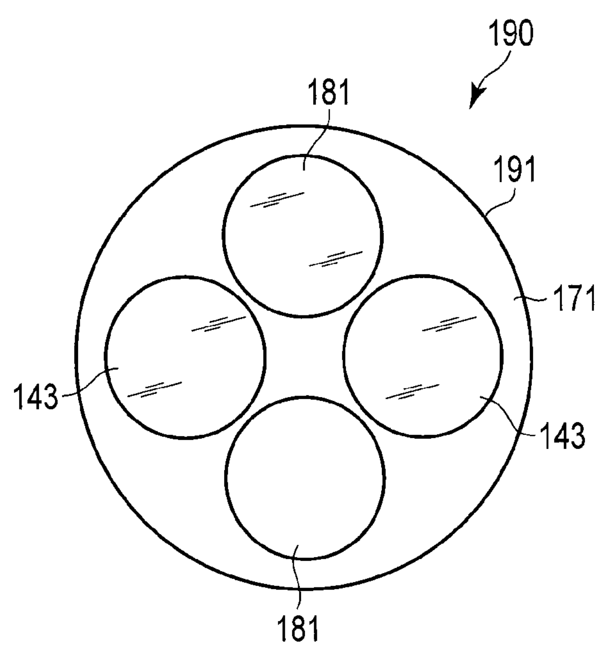
F I G. 6F



F I G. 7A
General Art



F I G. 7B
General Art

LIGHT SOURCE DEVICE FOR TUBULAR OBSERVATION DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation application of PCT Application No. PCT/JP2013/050831, filed Jan. 17, 2013 and based upon and claiming the benefit of priority from prior Japanese Patent Application No. 2012-010882, filed Jan. 23, 2012, the entire contents of all of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light source device with a high layout efficiency.

2. Description of the Related Art

Recently, space saving, lower power consumption, and higher luminance have been required for thin tubular light sources, and development thereof has been under way. Such a light source is disclosed in, for example, Jpn. Pat. Appln. KOKAI Publication No. 2006-173324.

In Jpn. Pat. Appln. KOKAI Publication No. 2006-173324, a high-performance light source device satisfies both high color rendering properties and high luminous efficiency that are in a trade-off relation.

This light source device includes a first semiconductor laser light source, a wavelength converting member, at least one first unit having a light guide, a second semiconductor laser light source, and at least one second unit having a wavelength converting member and a light guide.

The first semiconductor laser light source has a laser element which emits primary light of a blue wavelength region.

The wavelength converting member has one or more kinds of fluorescent substances. The fluorescent substance absorbs the primary light emitted from the first semiconductor laser light source, converts the wavelength thereof, and radiates light having a wavelength region longer than that of the primary light. This wavelength converting member functions as an illumination unit.

In the section of the light guide, the refractive index in the center is higher than the refractive index in the peripheral portion. The light guide guides the primary light emitted from the first semiconductor laser light source to the wavelength converting member.

The second semiconductor laser light source emits primary light having a wavelength region shorter than that of the primary light that the laser element emitted.

This light source device is provided in a tubular observation device, and the illumination unit is mounted at the distal end portion of the tubular observation device together with a second functional unit. The second functional unit has, for example, an imaging unit and an opening portion. This opening portion is provided, for example, to insert an optional member through the distal end portion. The tubular observation device is, for example, an endoscope.

FIG. **7**A and FIG. **7**B show front views of a distal end portion **191** (case) of a general tubular device **190**. As shown in FIG. **7**A, for example, the distal end face of one functional unit **181** and two illumination units **143** are provided in a distal end face **171** of the distal end portion **191**. As shown in FIG. **7**B, for example, the distal end faces of two functional units **181** and two illumination units **143** are provided in a distal end face **171** of the distal end portion **191**. The functional units **181** are, for example, an imaging unit and an opening portion.

In general, a distal end portion of the light guide has a circular shape. In general, the illumination unit **143** has a cylinder shape. Therefor primary light is emitted from the light guide in circular shape.

As shown in FIG. **7**A and FIG. **7**B, in general, the distal end portion **191** has a cylinder shape and the distal end face **171** has a circular shape for matching to emitting shape of primary light. As shown in FIG. **7**A and FIG. **7**B, in general, the distal end face **171** has a circular shape, the distal end portion **191** has a cylinder shape.

As shown in FIG. **7**A and FIG. **7**B, when the functional units **181** and the illumination unit **143** are provided adjacent to one another, a fill factor in the distal end portion **191** including distal end face **171** is decreased, a dead space is formed. That is, wasteful space is occurred and layout efficiency is decreased in the distal end portion **191** including distal end face **171**.

The present invention has been made under these circumstances, and an object of the invention is to provide a light source device which the formation of dead space is suppressed, wasteful space is eliminated, and layout efficiency is increased in the part in which the light source device is provided.

BRIEF SUMMARY OF THE INVENTION

An aspect of a light source device of the present invention includes a primary light source unit and a light converting unit, the primary light source unit includes a primary light emitting portion which emits primary light, the light converting unit includes a light converting member which converts the optical properties of the primary light when the primary light is applied thereto and which generates secondary light different from the primary light, and a secondary light emitting portion which emits the secondary light generated by the light converting member, wherein in the two-dimensional shape of the secondary light emitting portion projected on a surface perpendicular to the optical axis of the primary light, the length of the minimum width of the two-dimensional shape passing through the center of gravity of the two-dimensional shape is different from the length of the maximum width of the two-dimensional shape passing through the center of gravity.

Advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. Advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

FIG. **1**A is a schematic perspective view of a light source device according to a first embodiment of the present invention;

FIG. **1**B is a longitudinal sectional view of the light source device shown in FIG. **1**A;

FIG. **1**C is a front view of the light source device shown in FIG. **1**A;

FIG. **1**D is a perspective view of a holding member shown in FIG. **1**A;

FIG. **1**E is a diagram showing a layout plane in which an illumination unit and an imaging unit are provided;

FIG. **1**F is a diagram illustrating a layout plane, a region in which distal end portion surfaces of all functional units are disposed, and a layout possible region;

FIG. **2**A is a perspective view of a holding member having a triangular-prism shape;

FIG. **2**B is a front view of the holding member shown in FIG. **2**A;

FIG. **2**C is a diagram showing a layout plane in which the holding members shown in FIG. **2**A are provided;

FIG. **2**D is a perspective view of a holding member having a rectangular-prism shape;

FIG. **2**E is a front view of the holding member shown in FIG. **2**D;

FIG. **2**F is a diagram showing a layout plane in which the holding members shown in FIG. **2**D are provided;

FIG. **2**G is a diagram showing a layout plane in which holding members having a rhomboidal-prism shape are provided;

FIG. **2**H is a perspective view of a holding member having a hexagonal-prism shape;

FIG. **2**I is a front view of the holding member shown in FIG. **2**H;

FIG. **2**J is a diagram showing a layout plane in which the holding members shown in FIG. **2**H are provided;

FIG. **2**K is a diagram showing a layout plane in which holding members having a semicircular-cylinder shape are provided;

FIG. **2**L is a diagram showing a layout plane in which holding members having a semicircular-cylinder shape are provided;

FIG. **3**A is a schematic perspective view of a light source device according to a second embodiment of the present invention;

FIG. **3**B is a longitudinal sectional view of the light source device shown in FIG. **3**A;

FIG. **3**C is a front view of the light source device shown in FIG. **3**A;

FIG. **3**D is a perspective view of a holding member shown in FIG. **3**A;

FIG. **3**E is a diagram illustrating how primary light **77***a* and primary light **77***b* travel through a transmitting member;

FIG. **4**A is a schematic perspective view of a light source device according to a third embodiment of the present invention;

FIG. **4**B is a longitudinal sectional view of the light source device shown in FIG. **4**A;

FIG. **4**C is a front view of the light source device shown in FIG. **4**A;

FIG. **4**D is a front view of a transparent member shown in FIG. **4**A;

FIG. **5**A is a schematic perspective view of a light source device according to a fourth embodiment of the present invention;

FIG. **5**B is a longitudinal sectional view of the light source device shown in FIG. **5**A;

FIG. **5**C is a front view of the light source device shown in FIG. **5**A;

FIG. **5**D is a perspective view of a transparent member shown in FIG. **5**A;

FIG. **6**A is a schematic perspective view of a light source device according to a fifth embodiment of the present invention;

FIG. **6**B is a longitudinal sectional view of the light source device shown in FIG. **6**A;

FIG. **6**C is a front view of the light source device shown in FIG. **6**A;

FIG. **6**D is a schematic perspective view of the light source device shown in FIG. **6**A having more than one optical fiber, primary light emitting portions, and light converting members;

FIG. **6**E is a longitudinal sectional view of the light source device shown in FIG. **6**D;

FIG. **6**F is a front view of the light source device shown in FIG. **6**D;

FIG. **7**A shows a layout plane (front view) of the distal end portion of a general tubular observation device; and

FIG. **7**B shows a layout plane (front view) of the distal end portion of a general tubular observation device.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

For purposes of this Application, the term "trace" is defined as offset and/or parallel and/or coincident.

The first embodiment is described with reference to FIG. **1**A, FIG. **1**B, FIG. **1**C, FIG. **1**D, FIG. **1**E, and FIG. **1**F.

Hereinafter, in the traveling direction of primary light, the direction in which the primary light is emitted from a primary light emitting portion **25**, the front side in the traveling direction of primary light, and the side of a secondary light emitting portion **43** are referred to as forward. Moreover, in the traveling direction of primary light, the rear side in the traveling direction of primary light, and the side of a primary light source **21** are referred to as rearward. An axis on which the primary light is emitted from the center of the primary light emitting portion **25** is referred to as an optical axis. The distal end face (front surface) of a distal end portion **91** of a tubular device **90** is referred to as a layout plane **71**.

As a reflecting portion **45***c* is not shown in FIG. **1**A, some components are not shown in some of the drawings for simplicity.

As shown in FIG. **1**A and FIG. **1**B, a light source device **10** includes a primary light source unit **20** and a light converting unit **40**.

As shown in FIG. **1**A and FIG. **1**B, the primary light source unit **20** has the primary light sources **21** which emit primary light such as excitation light, optical fibers **23** serving as light guide members which guide the primary light emitted from the primary light sources **21** to the light converting unit **40**, and the primary light emitting portions **25** which are provided at the end portions of the optical fibers **23** and which emit the primary light guided by the optical fiber **23** to the light converting unit **40**.

As shown in FIG. **1**A and FIG. **1**B, the primary light sources **21** are, for example, point light sources having the following characteristics: emitting primary light having a straight traveling property, being high in the incidence efficiency of the primary light into the optical fibers **23**, being high in the efficiency of energy use, being low in power consumption, and being small in size. The primary light source **21** emits the primary light which causes excitation and light generation in a light converting member **41** of the light converting unit **40**. This primary light source **21** has, for example, a semiconductor laser light source or an LED. The primary light source **21** is optically connected to the optical fiber **23** via an unshown lens.

As shown in FIG. **1**B, for example, three primary light sources **21** are provided. These primary light sources **21** are provided adjacent to one another, apart from one another, and linearly beside one another in a direction that intersects at right angles with the optical axis.

As shown in FIG. **1**A and FIG. **1**B, the optical fiber **23** has, for example, a flexible circular-cylinder shape. The same number of optical fibers **23** as the primary light sources **21**, for example, three optical fibers **23** are provided. One end portion of one optical fiber **23** is optically connected to one primary light source **21**. These optical fibers **23** are provided adjacent to one another, apart from one another, and beside one another.

The optical fiber **23** has the property of efficiently guiding primary light. The optical fiber **23** is made of, for example, glass or plastics. The optical fiber **23** has, for example, a multifiber mode optical fiber. The optical fiber **23** has optical properties which allow the primary light to be highly efficiently guided forward so that the primary light is emitted forward from the primary light emitting portions **25** without any great energy loss. In this instance, the emission angle of the primary light is determined by the NA of the optical fiber **23** and the refractive index of the light converting member **41**.

As shown in FIG. **1**A and FIG. **1**B, one primary light emitting portion **25** is provided at the other end portion of one optical fiber **23**. Therefore, the same number of primary light emitting portions **25** as the optical fibers **23**, for example, three primary light emitting portions **25** are provided. The primary light emitting portion **25** is an emission surface to emit the primary light, and is the end face of the optical fiber **23**. The primary light emitting portion **25** has the same shape as, for example, the other end portion of one optical fiber **23**, and has, for example, a circular shape. Therefore, a beam spot formed by the primary light emitted from one primary light emitting portion **25** has a circular shape.

In this instance, the beam spot shows an irradiation region of the primary light projected on a surface perpendicular to the optical axis. The beam spot is defined as a region which is irradiated at an intensity higher than at least $1/e^2$ of the maximum intensity of the primary light. e is Napier's constant as a base of a natural logarithm.

According to the present embodiment, as shown in FIG. **1**B and FIG. **1**C, the optical fibers **23** are provided adjacent to one another, apart from one another, and beside one another along the direction (maximum width direction) that intersects at right angles with the optical axis, as described above. Therefore, the primary light emitting portions **25** are provided in a similar manner as the optical fibers **23**. Thus, the beam spot formed by the primary light emitted from all three primary light emitting portions **25** does not have a circular shape. In this case, the beam spot has a shape in which circles are provided beside one another along the direction that intersects at right angles with the optical axis so that the edge of one circle is located in contact with or apart from the edge of another circle. Alternatively, the beam spot has a shape in which circles are provided beside one another along the direction that intersects at right angles with the optical axis so that a part of one circle overlaps a part of another adjacent circle.

The shape of the beam spot is then converted by the arrangement of the primary light emitting portions **25** so that, for example, the shape of the beam spot in a first direction is shorter and the shape of the beam spot in a second direction is longer. As shown in FIG. **1**C, the first direction represents, for example, the direction that intersects at right angles with the optical axis, and represents a later-described minimum width direction of the secondary light emitting portion **43**. As shown in FIG. **1**C, the second direction represents, for example, the direction that intersects at right angles with the optical axis and the first direction, and represents a later-described maximum width direction of the secondary light emitting portion **43**. Thus, the light source device **10** further includes a shape converting unit **60** which converts, to a desired shape, the shape of the beam spot of the primary light emitted from the primary light emitting portions **25** and projected on the bottom surface of the light converting member **41**. As shown in FIG. **1**C, the primary light emitting portions **25** function as the shape converting unit **60**.

As shown in FIG. **1**A and FIG. **1**B, the light converting unit **40** has the light converting member **41** which converts the optical properties of the primary light when the primary light is applied thereto and which generates secondary light different from the primary light, the secondary light emitting portion **43** which is provided in the light converting member **41** and which emits the secondary light, and a holding member **45** which holds the light converting member **41** and the optical fibers **23**.

The light converting member **41** absorbs the primary light, and then converts the wavelength of the absorbed primary light to a wavelength different from that of the primary light to generate the secondary light having this wavelength. Thus, the light converting member **41** is a wavelength converting member which converts the wavelength of the primary light, and is an optical element which functions when the primary light is applied thereto. The light converting member **41** has, for example, a fluorescent material. When the secondary light emitting portion **43** emits, for example, white illumination light as the secondary light, the secondary light emitting portion **43** is formed by several kinds of powder fluorescent materials and a transparent resin. In this instance, several kinds of powder fluorescent materials are in combination with one another and dispersed into the resin, and the resin is solidified in this state so that the light converting member **41** is shaped.

As shown in FIG. **1**A, the light converting member **41** has, for example, an elliptic-cylinder shape. The light converting member **41** has thickness and concentration that can sufficiently absorb the primary light emitted from the primary light emitting portions **25**. The bottom surface of the light converting member **41** has an elliptic shape. As shown in FIG. **1**A and FIG. **1**B, the area of this bottom surface is larger than the area of the minimum ellipse covering all the primary light emitting portions **25**. In the center of the bottom surface, the circumference of the center including the center of the bottom surface is in abutment with the primary light emitting portions **25**. The minor axis direction (minimum width direction) of the light converting member **41** including the bottom surface represents the first direction shown in FIG. **1**C, and is provided along the direction that intersects at right angles with the optical axis. The major axis direction (maximum width direction) of the light converting member **41** including the bottom surface represents the second direction shown in FIG. **1**C, and is provided along a direction in which the optical fibers **23** (primary light emitting portions **25**) are provided beside one another, that is, a direction that intersects at right angles with the optical axis direction and the minor axis direction.

The secondary light emitting portion **43** shown in FIG. **1**A and FIG. **1**B is also an illumination unit which illuminates an imaging target with the secondary light. Therefore, the secondary light emitting portion **43** is also provided in the forefront of the light converting member **41**. The secondary light emitting portion **43** is provided along the surface perpendicular to the optical axis. The secondary light emitting portion **43** is formed as a plane. This secondary light emitting portion **43** functions as, for example, the upper surface of the light converting member **41**. Thus, as shown in FIG. **1**C, the secondary light emitting portion **43** has, for example, an elliptic shape. As shown in FIG. **1**C, as regards the shape of the secondary light emitting portion **43**, the length of the minimum width of the secondary light emitting portion **43** passing through the center of gravity of the secondary light emitting portion **43** is different from the length of the maximum width of the secondary light emitting portion **43** passing through the center of gravity of the secondary light emitting portion **43**. This minimum width represents, for example, the minimum length in the distance (length) from the edge of the secondary light emitting portion **43** to the opposite edge passing through the center of gravity of the secondary light emitting portion **43**. The maximum width represents, for example, the maximum length in the distance (length) from the edge of the secondary light emitting portion **43** to the opposite edge passing through the center of gravity of the secondary light emitting portion **43**. In this instance, as shown in FIG. **1**C, the minor axis direction (minimum width direction) of the secondary light emitting portion **43** represents the first direction, and is a direction that intersects at right angles with the optical axis. The major axis direction (maximum width direction) of the secondary light emitting portion **43** represents the second direction as shown in FIG. **1**C, and is a direction in which the optical fibers **23** (primary light emitting portions **25**) are provided beside one another.

To sum up, it is represented that, as regards the two-dimensional shape of the secondary light emitting portion **43** projected on the surface perpendicular to the optical axis of the primary light, the length of the minimum width of the two-dimensional shape passing through the center of gravity of the two-dimensional shape is different from the length of the maximum width of the two-dimensional shape passing through the center of gravity.

The holding member **45** shown in FIG. **1**A and FIG. **1**B is made of at least one of, for example, zirconia, glass, and a metal. This metal is made of at least one of, for example, nickel, SUS, and brass. The holding member **45** has, for example, an elliptic shape.

As shown in FIG. **1**D, the holding member **45** has therein rear holding hole portions **45***a* which hold the optical fibers **23**, and a front holding hole portion **45***b* which holds the light converting member **41**. The rear holding hole portions **45***a* are provided in the rear of the front holding hole portion **45***b* in the axial direction of the holding member **45**. The rear holding hole portions **45***a* are exposed to the outside in the rear part of the holding member **45**, and the front holding hole portion **45***b* is exposed to the outside in the front part of the holding member **45**. The rear holding hole portions **45***a* are in communication with the bottom surface of the front holding hole portion **45***b*.

As shown in FIG. **1**D, the same number of rear holding hole portions **45***a* as the optical fibers **23**, for example, three rear holding hole portions **45***a* are provided. As shown in FIG. **1**A and FIG. **1**B, one optical fiber **23** is provided in one rear holding hole portion **45***a*. The rear holding hole portion **45***a* has the same shape as the optical fiber **23**, for example, a circular-cylinder shape, and has the same size as the optical fiber **23**. The optical fibers **23** are fitted to or adhesively bonded to the rear holding hole portions **45***a*. These rear holding hole portions **45***a* are provided parallel to one another along the optical axis. As shown in FIG. **1**C, the rear holding hole portions **45***a* are provided adjacent to one another, apart from one another, and linearly beside one another along the second direction.

As shown in FIG. **1**D, one front holding hole portion **45***b* is provided. As shown in FIG. **1**A and FIG. **1**B, the front holding hole portion **45***b* has the same shape as the light converting member **41**, for example, a circular-cylinder shape. Thus, the outside diameter and height of the front holding hole portion **45***b* are substantially the same as the outside diameter and height of the light converting member **41**. The volume of the front holding hole portion **45***b* is substantially the same as the volume of the light converting member **41**. The light converting member **41** is fitted to or adhesively bonded to the front holding hole portion **45***b*. The front holding hole portion **45***b* is larger than the area of the minimum ellipse covering all the primary light emitting portions **25**.

In the front holding hole portion **45***b* having the elliptic-cylinder shape, the minor axis direction (minimum width direction) of the front holding hole portion **45***b* represents the first direction as shown in FIG. **1**C, and is provided along the direction that intersects at right angles with the optical axis. The major axis direction (maximum width direction) of the front holding hole portion **45***b* represents the second direction as shown in FIG. **1**C, and is provided along the direction in which the optical fibers **23** (primary light emitting portions **25**) are provided beside one another.

The distal end face (front surface) of the holding member **45** in which the front holding hole portion **45***b* is provided has a hollow elliptic shape. The size of the outer shape of this distal end face is larger than the size of the secondary light emitting portion **43**, and is similar to the size of the secondary light emitting portion **43**.

As shown in FIG. **1**C, the front holding hole portion **45***b* has the reflecting portion **45***c* which is provided on the inner circumferential surface and bottom surface of the front holding hole portion **45***b* and which highly efficiently reflects the primary light and the secondary light. The reflecting portion **45***c* is made of a material having a function to reflect visible light. This material represents, for example, silver or aluminum. The reflecting portion **45***c* is provided on the inner circumferential surface and bottom surface of the front holding hole portion **45***b* by, for example, a plating method, a vapor deposition method, or a sputtering method. Because of the general optical properties of the light converting member **41**, the reflecting portion **45***c* reflects forward the secondary light which has been emitted from the secondary light emitting portion **43** in all directions.

As shown in FIG. **1**B, the holding member **45** directly holds therein the optical fibers **23** and the light converting member **41** by the rear holding hole portions **45***a* and the front holding hole portion **45***b* so that the optical fibers **23** and the light converting member **41** are optically coupled to each other inside the holding member **45**. The optical fibers **23** which are fitted to or adhesively bonded to the rear holding hole portions **45***a* and the light converting member **41** which is fitted to or adhesively bonded to the front holding hole portion **45***b* are in direct abutment with each other inside the holding member **45**. More specifically, the primary light emitting portion **25** and the bottom surface of the light converting member **41** are in abutment with each other.

As shown in FIG. **1**E, this light converting unit **40** is incorporated in the distal end portion **91** of the tubular device **90** together with at least one functional unit **81**. The functional unit **81** has, for example, an imaging unit and an opening portion. The distal end portion **91** has, for example, a circular-cylinder shape, and is a case. The layout plane **71** which is the distal end face of the distal end portion **91** has, for example, a circular shape. In this case, the light converting unit **40** is embedded in the distal end portion **91** so that the secondary light emitting portion **43** and the distal end face of the holding member **45** are provided in the layout plane **71** and so that the secondary light emitting portion **43** and the distal end face of the holding member **45** are exposed to the outside. The functional units **81** are embedded in the distal end portion **91** so that the distal end faces of all the functional units **81** are provided in the layout plane **71** and so that the distal end faces of the functional units **81** are exposed to the outside.

In this instance, at least part of an outline **43***a* of the two-dimensional shape of the secondary light emitting portion **43** traces an edge **71***a* of the layout plane **71**. This two-dimensional shape represents a shape formed when the secondary light emitting portion **43** is projected on the surface perpendicular to the optical axis of the primary light. That is, at least part of the outline **43***a* of the secondary light emitting portion **43** traces the edge **71***a* of the layout plane **71**. In other words, at least part of the outline **43***a* is offset relative to the edge **71***a* of the layout plane **71**. In other words again, at least part of the outline **43***a* is parallel to the edge **71***a* of the layout plane **71**, and extends along the edge **71***a* of the layout plane **71**.

As shown in FIG. **1**F, the layout plane **71** has a region **73** in which the distal end faces of all the functional units **81** are disposed, and a layout possible region **75** representing a region in which the region **73** is removed from the layout plane **71**. In other words, the layout possible region **75** represents a region in which the secondary light emitting portion **43** can be disposed in the layout plane **71**. Therefore, the layout possible region **75** is surrounded by the edge **71***a* of the layout plane **71** and an edge **73***a* of the region **73**. In this instance, part of an edge **75***a* of the layout possible region **75** has, for example, an arc shape.

The secondary light emitting portion **43** is provided in the layout possible region **75** so that The secondary light emitting portion **43** is exposed to the outside. At least part of the outline **43***a* of the two-dimensional shape has a shape that traces part of the edge **75***a* of the layout possible region **75**, and has, for example, an elliptic shape. More specifically, at least part of the outline **43***a* of the secondary light emitting portion **43** traces the edge **75***a* of the layout possible region **75**, and has an elliptic shape.

Although at least part of the outline **43***a* of the secondary light emitting portion **43** traces the edge **71***a* of the layout plane **71**, the present invention does not need to be limited to this. For example, at least part of the outline of the distal end face of the holding member **45** or at least part of the outline of the holding member **45** may trace the edge **71***a* of the layout plane **71**.

Now, an operation method according to the present embodiment is described.

Primary light is emitted from the primary light source **21**, guided to the primary light emitting portions **25** by the optical fiber **23**, and emitted toward the light converting member **41** by the primary light emitting portions **25**. The shape of the beam spot of the primary light emitted from the three primary light emitting portions **25** is converted to correspond to the shape of the secondary light emitting portion **43** by the arrangement of the primary light emitting portions **25**, i.e., by the shape converting unit **60**. In this state, the primary light incidents the light converting member **41**, and is converted to secondary light by the light converting member **41**. The secondary light travels through the light converting member **41**. In this instance, some of the secondary light travels toward the reflecting portion **45***c*, is reflected forward by the reflecting portion **45***c*, and is emitted to the outside from the secondary light emitting portion **43**. The rest of the secondary light directly travels to the secondary light emitting portion **43**, and is emitted to the outside from the secondary light emitting portion **43**.

As shown in FIG. **1**C and FIG. **1**D, the secondary light emitting portion **43** has, for example, an elliptic shape, and at least part of the outline **43***a* of the secondary light emitting portion **43** traces the edge **75***a* of the layout possible region **75**. Thus, according to the present embodiment, the formation of dead space in the layout plane **71** is suppressed, wasteful space in the layout plane **71** is eliminated, and layout efficiency is increased, as compared with the structure shown in FIG. **7**A.

As shown in FIG. **1**A, FIG. **1**C, and FIG. **1**E, the light converting member **41** and the holding member **45** have, for example, an elliptic-cylinder shape to correspond to the secondary light emitting portion **43**, and at least part of the outline of the distal end face of the holding member **45** and at least part of the outline of the holding member **45** trace the edge **75***a* of the layout possible region **75**. Thus, according to the present embodiment, the formation of dead space in the distal end portion **91** is suppressed, wasteful space in the distal end portion **91** is eliminated, and layout efficiency is increased, as compared with the structure shown in FIG. **7**A.

As shown in FIG. **1**B and FIG. **1**C, three optical fibers **23** are provided for one light converting member **41**. In this instance, the optical fibers **23** and the primary light emitting portions **25** are provided adjacent to one another, apart from one another, and beside one another along the major axis direction (maximum width direction) of the secondary light emitting portion **43**. Thus, as shown in FIG. **1**B and FIG. **1**C, in the bottom surface of the light converting member **41** having the elliptic shape, the formation of dead space is suppressed, wasteful space is eliminated, and layout efficiency is increased. The primary light fully illuminates the light converting member **41**.

The arrangement of the optical fibers **23** (primary light emitting portions **25**), i.e., the shape converting unit **60** is converted so that the shape of the beam spot of the primary light corresponds to the shape of the secondary light emitting portion **43**. Thus, the shape of the beam spot of the primary light is short in the minimum width direction of the secondary light emitting portion **43** and long in the maximum width direction of the secondary light emitting portion **43**. In this state, the primary light illuminates the light converting member **41**.

Since three optical fibers **23** are provided, the primary light is dispersed into three parts and then illuminates the light converting member **41**. Thus, the places where heat is generated in the optical fibers **23** are dispersed into three places, and heat in the light source device **10** is also dispersed. As a result, the primary light fully and more strongly illuminates the light converting member **41**. The secondary light is then fully and more strongly emitted.

As shown in FIG. **1**B, the area of the bottom surface of the light converting member **41** is larger than the area of the minimum ellipse covering all the primary light emitting portions **25**. Therefore, the primary light emitted from the three primary light emitting portions **25** illuminates the light converting member without leakage.

The reflecting portion **45***c* reflects the secondary light forward, and the secondary light emitting portion **43** fully emits the secondary light.

In general, when the minor axis of an ellipse has the same length as the diameter of a circle, the area of the ellipse is larger than the area of the circle. Therefore, the secondary light emitting portion **43** having an elliptic shape is larger than the secondary light emitting portion **43** having a circular shape. That is, the light emitting surface of the secondary light emitting portion **43** having an elliptic shape is larger than the light emitting surface of the secondary light emitting portion **43** having a circular shape. Thus, more secondary light is emitted. The secondary light emitting portion **43** according to the present embodiment surface-emits the secondary light to the imaging target even if the distal end face of the distal end portion **91** is close to the imaging target. Therefore, according to the present embodiment, it is possible to provide an environment in which the imaging target is uniformly illuminated.

Thus, according to the present embodiment, as shown in FIG. **1**C and FIG. **1**E, the secondary light emitting portion **43** has, for example, an elliptic shape, and at least part of the outline **43***a* of the secondary light emitting portion **43** traces the edge **75***a* of the layout possible region **75**. Thus, according to the present embodiment, in the layout plane **71**, the formation of dead space is suppressed, wasteful space is eliminated, and layout efficiency is increased, as compared with the structure shown in FIG. **7**A.

According to the present embodiment, as shown in FIG. **1**A, FIG. **1**C, and FIG. **1**E, the light converting member **41** and the holding member **45** have, for example, an elliptic-cylinder shape to correspond to the secondary light emitting portion **43**, and at least part of the outline of the distal end face of the holding member **45** and at least part of the outline of the holding member **45** trace the edge **75***a* of the layout possible region **75**. Thus, according to the present embodiment, in the distal end portion **91** representing the part in which the light converting unit **40** is provided, the formation of dead space can be suppressed, wasteful space can be eliminated, and layout efficiency can be increased, as compared with the structure shown in FIG. **7**A.

According to the present embodiment, as shown in FIG. **1**C, the optical fibers **23** and the primary light emitting portions **25** are provided along the major axis direction (maximum width direction) of the secondary light emitting portion **43**. Thus, according to the present embodiment, in the bottom surface of the light converting member **41** having the elliptic shape, the formation of dead space can be suppressed, wasteful space can be eliminated, and layout efficiency can be increased. According to the present embodiment, the primary light can fully illuminate the light converting member **41**.

According to the present embodiment, the shape converting unit **60** converts the shape of the beam spot of the primary light to correspond to the shape of the secondary light emitting portion **43**. Thus, according to the present embodiment, the light converting member **41** including the secondary light emitting portion **43** can be disposed in the distal end portion **91** including the layout possible region **75** without wasting space.

According to the present embodiment, the primary light emitting portions **25** function as the shape converting unit **60**. Thus, according to the present embodiment, it is not necessary to provide any new member for the shape converting unit **60**, and the configuration of the light source device **10** can be simpler.

According to the present embodiment, the primary light can be applied to substantially the entire bottom surface of the light converting member **41** by the shape converting unit **60**. Thus, according to the present embodiment, local heat generation can be prevented in the bottom surface of the light converting member **41**, stronger primary light can be applied to the bottom surface, and bright secondary light can be emitted. According to the present embodiment, the light source device **10** that is bright can be provided.

According to the present embodiment, the secondary light emitting portion **43** has an elliptic shape. However, the shape of the secondary light emitting portion **43** is not limited to this as long as the formation of dead space can be suppressed, wasteful space can be eliminated, and layout efficiency can be increased.

For example, the two-dimensional shape has one rotation symmetry axis, and this rotation symmetry axis has only to be a twofold or more and sixfold or less rotation axis. Thus, for example, the secondary light emitting portion **43** has only to have at least one of an elliptic shape shown in FIG. **1**C, a triangular shape shown in FIG. **2**A, FIG. **2**B, and FIG. **2**C, a quadrangular shape such as a rectangle shown in FIG. **2**D, FIG. **2**E, and FIG. **2**F, a rhombic shape shown in FIG. **2**G, and a parallelogram, a pentangular shape, a hexangular shape shown in FIG. **2**H, FIG. **2**I, and FIG. **2**J, a semicircular shape shown in FIG. **2**K and FIG. **2**L, and a shape at least partly having an arc or an elliptic arc as shown in FIG. **1**C, FIG. **2**K, and FIG. **2**L.

That is, that at least part of the outline **43***a* traces the edge **75***a* of the layout possible region **75** represents that at least part of the outline **43***a* is configured by at least one of a curve and a straight line to trace the edge **75***a*. Thus, it is possible to suppress the formation of dead space between the outline **43***a* and the edge **75***a*. Accordingly, in the layout plane **71**, it is possible to eliminate wasteful space, and increase layout efficiency.

It is preferable that when the secondary light emitting portion **43** has a shape having arc, the curvature of the arc is the same as the curvature of the edge **75***a* of the layout possible region **75**.

For example, when the secondary light emitting portion **43** has a polygonal shape as shown in FIG. **2**A, the vertexes may be formed by curves.

The light converting member **41**, the rear holding hole portions **45***a*, and the holding member **45** have only to have a cylindrical shape that traces the shape of the secondary light emitting portion **43**.

According to the present embodiment, the light converting member **41** has, for example, a fluorescent material. However, the present invention does not need to be limited to this.

A: For example, the light converting member **41** may have at least one of a concave lens, a convex lens, a hologram lens, and a diffraction grating. The concave lens, the convex lens, and a combination of the concave lens and the convex lens function as a radiation angle conversion member which converts the radiation angle of the secondary light. The hologram lens and the diffraction grating function as the radiation angle conversion member, or as a radiation conversion member which converts the radiation direction of the secondary light.

B: For example, the light converting member **41** may be made of a resin or glass in which particles are dispersed. The particles are, for example, alumina having a high refractive index and a high reflectivity. Alternatively, for example, the light converting member **41** may be made of transparent members different in refractive index. Alternatively, for example, the light converting member **41** may be formed by a scattering plate such as frosted glass, or by a diffusion plate having minute depressions and projections provided in its surface.

C: For example, the light converting member **41** may be made of a spectrum conversion member having at least one of an optical semiconductor material, a second harmonic generation (SHG) material, and a photoluminescent material.

D, E: The light converting member **41** may be formed by a member which transmits some of the primary light and blocks the rest of the primary light.

D: This member is, for example, an optical filter. This optical filter represents, for example, at least one of a wavelength cut filter, a dye filter, and an optical resonator (etalon).

E: This member is, for example, a light transmitting modulation member. The light transmitting modulation member represents, for example, at least one of an optical switch, an electrochromic element, and a liquid crystal device.

For example, B and D are suited to the safety of the primary light source **21** and speckle removal. When the primary light source **21** emits primary light representing at least one of lamp light and LED light and the radiation angle of this primary light is adjusted, at least one of A and B can be used.

The light converting member **41** does not need to be limited to the above, and may be configured by a combination of the above.

According to the present embodiment, in the light converting member **41**, the rear holding hole portions **45***a*, and the front holding hole portion **45***b*, their diameters art constant from the front to the rear. However, the present invention does not need to be limited to this as long as the secondary light is efficiently emitted from the secondary light emitting portion **43**. The light converting member **41**, the rear holding hole portions **45***a*, and the front holding hole portion **45***b* may have at least one of an elliptical-cone shape, an elliptical-paraboloid shape, and a partly cut elliptic shape in which the bottom surface that is in abutment with the primary light emitting portions **25** is the vertex.

Now, the second embodiment according to the present invention is described with reference to FIG. **3**A, FIG. **3**B, FIG. **3**C, FIG. **3**D, and FIG. **3**E.

As shown in FIG. **3**A and FIG. **3**B, according to the present embodiment, in the primary light source unit **20**, one primary light source **21** is provided, one optical fiber **23** is provided, and one primary light emitting portion **25** is provided.

As shown in FIG. **3**A, FIG. **3**B, FIG. **3**C, and FIG. **3**D, according to the present embodiment, in the light converting unit **40**, one rear holding hole portion **45***a* is provided, and is provided, for example, on the central axis of the holding member **45**.

As shown in FIG. **3**A and FIG. **3**B, the light converting unit **40** further has a transmitting member **49** which is a transmitting region **47** to transmit primary light and secondary light. The transmitting member **49** is held by the front holding hole portion **45***b*, and is provided between the primary light emitting portion **25** and the light converting member **41**. in the optical axis direction. That is, the transmitting member **49** is provided in the rear of the light converting member **41**. Thus, the light converting member **41** is mounted in the transmitting member **49**.

As shown in FIG. **3**A and FIG. **3**B, the transmitting member **49** has the same shape as the light converting member **41**, for example, an elliptic-cylinder shape. The upper surface of the transmitting member **49** has the same size as the bottom surface of the light converting member **41**, and is in abutment with the bottom surface of the light converting member **41**. The center of a bottom surface **49***a* of the transmitting member **49** is in abutment with the primary light emitting portion **25**. The bottom surface **49***a* is formed flat. The transmitting member **49** is made of, for example, glass.

As shown in FIG. **3**A and FIG. **3**B, the reflecting portion **45***c* is provided on the inner circumferential surface and bottom surface of the front holding hole portion **45***b*, as in the first embodiment. Thus, the reflecting portion **45***c* is provided on the lateral side of the light converting member **41**, on the lateral side of the transmitting member **49**, and on the lower side of the transmitting member **49** except for the primary light emitting portion **25**, and highly efficiently reflects the primary light and the secondary light.

Now, an operation method according to the present embodiment is described.

According to the present embodiment, since only one primary light emitting portion **25** is provided, the primary light is emitted from the primary light emitting portion **25**, and is incident the transmitting member **49** so that the beam spot has a circular shape.

In this instance, the primary light with a desired light distribution travels through the transmitting member **49**, and illuminates the bottom surface of the light converting member **41**. The desired light distribution represents that the amount of the primary light is maximized in the normal direction of the primary light emitting portion **25**, that the primary light is not inclined relative to the optical axis, and that the amount of the primary light is smaller when the inclination angle of the primary light relative to the optical axis is greater.

The inclination angle of the primary light which is emitted from the primary light emitting portion **25** toward the transmitting member **49** and which has an intensity higher than $1/e^2$ of the intensity of the primary light in the optical axis direction is defined as a critical intensity emission angle. e is Napier's constant as a base of a natural logarithm.

Thus, some of the primary light enters the transmitting member **49**, and travels through the transmitting member **49** at the critical intensity emission angle. In this instance, as shown in FIG. **3**E, this primary light includes primary light **77***a* which travels in at least the minor axis direction (minimum width direction) of the bottom surface **49***a* of the transmitting member **49**, and primary light **77***b* which travels in at least the major axis direction (maximum width direction) of the bottom surface **49***a* of the transmitting member **49**.

As shown in FIG. **3**E, the primary light **77***a* travels through the transmitting member **49** so that the primary light **77***a* travels from the primary light emitting portion **25** toward the reflecting portion **45***c* provided on the inner circumferential surface of the front holding hole portion **45***b*. The primary light **77***a* is then reflected by the reflecting portion **45***c*, and travels through the transmitting member **49** so that the primary light **77***a* travels toward the center of the bottom surface of the light converting member **41**. The primary light **77***a* then illuminates the periphery of the center of the bottom surface of the light converting member **41**.

As shown in FIG. 3E, the primary light 77*b* does not travel through the transmitting member **49** so that the primary light **77***b* travels from the primary light emitting portion **25** toward the reflecting portion **45***c*. The primary light **77***b* travels through the transmitting member **49** so that the primary light **77***b* travels from the primary light emitting portion **25** directly toward a position located apart from the center of the bottom surface of the light converting member **41**. The primary light **77***b* then directly illuminates the bottom surface. In this instance, the primary light **77***b* illuminates the position located apart from the center of the bottom surface.

To this end, it is necessary for the transmitting member **49** to convert the shape of the beam spot of the primary light to the shape of the bottom surface of the light converting member **41** so that the diameter of the beam spot of the primary light which illuminates the bottom surface of the light converting member **41** is the same as or shorter than the major axis of the bottom surface and longer than the minor axis of the bottom surface even if the transmitting member **49** extends infinitely in a direction perpendicular to the optical axis and the reflecting portion **45***c* is not provided.

As a result, the primary light having a circular shape is emitted from the primary light emitting portion **25**, and converted by the reflecting portion **45***c* and the transmitting member **49** to a state having a shape corresponding to the bottom surface of the light converting member **41** from the state having the circular shape. The primary light then illuminates the bottom surface of the light converting member **41** in this state. Thus, the reflecting portion **45***c* and the transmitting member **49** function as the shape converting unit **60**.

The light converting member **41**, the front holding hole portion **45***b*, and the transmitting member **49** are formed so that the above operation is possible.

Thus, according to the present embodiment, the shape of the beam spot of the primary light can be converted by the transmitting member **49** to correspond to the shape of the bottom surface of the light converting member **41** even if one optical fiber **23** is provided and one primary light emitting portion **25** is provided. Therefore, according to the present embodiment, the primary light can be applied to the entire bottom surface of the light converting member **41**, and the primary light can be dispersed and applied to the entire bottom surface of the light converting member **41**. Thus, according to the present embodiment, the position where heat is generated when the light converting member **41** generates secondary light can be dispersed, stronger primary light can be brought into the light converting member **41**, and the secondary light can be brighter. Moreover, according to the present embodiment, the holding member **45** can be more elongate and smaller in size, so that the holding member **45** can be more easily disposed in the distal end portion **91**.

Although the transmitting region **47** has the transmitting member **49** according to the present embodiment, the present invention does not need to be limited to this. The transmitting region **47** may have at least one of the transmitting member **49** and a gap portion. For example, the gap portion is formed between the light converting member **41** and the primary light emitting portion **25** when the light converting member **41** is provided apart from the primary light emitting portion **25**. This gap portion is filled with, for example, air.

Now, the third embodiment according to the present invention is described with reference to FIG. 4A, FIG. 4B, FIG. 4C, and FIG. 4D.

The transmitting member **49** according to the present embodiment shown in FIG. 4A, FIG. 4B, and FIG. 4C has different refractive indexes in a plane that intersects at right angles with the optical axis of the primary light. Thus, as shown in FIG. 4D, the transmitting member **49** has high refractive regions **49***b* provided along the minor axis direction (minimum width direction) of the transmitting member **49**, and low refractive regions **49***c* provided along the major axis direction (maximum width direction) of the transmitting member **49**. The refractive index of the low refractive regions **49***c* is lower than the refractive index of the high refractive regions **49***b*. This transmitting member **49** is, for example, a GRIN lens. The transmitting member **49** including the high refractive regions **49***b* and the low refractive regions **49***c* is made of, for example, glass. The transmitting member **49** functions as the shape converting unit **60**.

As shown in FIG. 4D, two high refractive regions **49***b* are provided, and two low refractive regions **49***c* are provided. The high refractive regions **49***b* and the low refractive regions **49***c* have, for example, a fan-shape. The high refractive regions **49***b* and the low refractive regions **49***c* are alternately provided adjacent to one another in the circumferential direction of the transmitting member **49** so that the refractive index changes by stages from the minor axis direction of the transmitting member **49** toward the major axis direction of the transmitting member **49**.

According to the present embodiment, the primary light does not travel to the reflecting portion **45***c*, and only travels toward the bottom surface of the light converting member **41** and directly illuminates the bottom surface of the light converting member **41**. The primary light travels through the low refractive region **49***c* at a greater angle than when passing through the high refractive region **49***b*.

Thus, according to the present embodiment, advantageous effects similar to those according to the second embodiment can be obtained.

According to the present embodiment, the refractive index changes by stages from the minor axis direction toward the major axis direction because of the high refractive regions **49***b* and the low refractive regions **49***c*. However, the present invention does not need to be limited to this. The refractive index may gradually change from the minor axis direction of the transmitting member **49** toward the major axis direction of the transmitting member **49**.

Now, the fourth embodiment according to the present invention is described with reference to FIG. 5A, FIG. 5B, FIG. 5C, and FIG. 5D.

As shown in FIG. 5A and FIG. 5B, according to the present embodiment, the transmitting member **49** is provided apart from the primary light emitting portion **25**. Thus, a gap portion **51** is provided between the transmitting member **49** and the primary light emitting portion **25**. The gap portion **51** is filled with, for example, air.

According to the present embodiment, as shown in FIG. 5B and FIG. 5D, the transmitting member **49** has the bottom surface **49***a* which faces the primary light emitting portion **25** and which scatters the primary light in a desired one direction. The bottom surface **49***a* faces the primary light emitting portion **25** via the gap portion **51**, and is larger than the primary light emitting portion **25**. The bottom surface **49***a* has a rugged shape. In the bottom surface **49***a*, grooves **49***d* are provided along the minor axis direction. The shape of the grooves **49***d* is at least one of a wave shape, a triangular shape, and a rectangular shape. The bottom surface **49***a* scatters the primary light in a desired direction such as the major axis direction by the rugged shape. The transmitting member **49** illuminates the light converting member **41** in this state. The transmitting member **49** functions as the shape converting unit **60**.

Thus, according to the present embodiment, advantageous effects similar to those according to the second embodiment can be obtained. Moreover, according to the present embodiment, the primary light can be applied to the light converting member **41** from various directions by the rugged bottom surface **49***a*.

Now, the fifth embodiment according to the present invention is described with reference to FIG. **6**A, FIG. **6**B, and FIG. **6**C.

As shown in FIG. **6**A, FIG. **6**B, and FIG. **6**C, the light converting member **41** according to the present embodiment has a circular-cylinder shape, and is smaller than the front holding hole portion **45***b*. The light converting member **41** has the thickness that can sufficiently absorb the primary light emitted from the primary light emitting portion **25**. The light converting member **41** includes, for example, a fluorescent material.

The primary light and the secondary light pass through the transmitting member **49** according to the present embodiment. This transmitting member **49** is made of, for example, transparent glass or resin which transmits visible light. The transmitting member **49** functions as the shape converting unit **60**.

The transmitting member **49** has the same size as the front holding hole portion **45***b*, and has, for example, an elliptic-cylinder shape. Thus, the outside diameter and height of the transmitting member **49** are substantially the same as the outside diameter and height of the front holding hole portion **45***b*. The volume of the transmitting member **49** is substantially the same as the remainder of the volume of the front holding hole portion **45***b* from which the volume of the light converting member **41** is subtracted. The transmitting member **49** is fitted to or adhesively bonded to the front holding hole portion **45***b*. The center of the bottom surface **49***a* of the transmitting member **49** abuts on the primary light emitting portion **25**.

The transmitting member **49** has a depression portion **49***e* which is provided on the upper surface side of the transmitting member **49** and to which the light converting member **41** can be fitted or adhesively bonded. The depression portion **49***e* has a circular-cylinder shape so that the light converting member **41** can be disposed therein. The depression portion **49***e* is provided on, for example, the central axis of the transmitting member **49** so that the entire primary light emitted from the primary light emitting portion **25** illuminates the bottom surface of the light converting member **41**. The depression portion **49***e* is not penetrated through the transmitting member **49** in the axial direction of the transmitting member **49**. Therefore, the light converting member **41** provided in the depression portion **49***e* is provided apart from the primary light emitting portion **25**, and faces the primary light emitting portion **25** via the transmitting member **49**. The side surface and the bottom surface of the light converting member **41** abut on the inner circumferential surface of the transmitting member **49**, and the light converting member **41** is surrounded by the transmitting member **49**. Thus, the transmitting member **49** surrounds the lateral side of the light converting member **41**, and is provided between the primary light emitting portion **25** and the light converting member **41**, and the primary light and the secondary light pass through the transmitting member **49**.

The transmitting member **49** is provided so that the secondary light does not travel into the light converting member **41** but travels toward the secondary light emitting portion **43** through the transmitting member **49** when the secondary light is emitted rearward from the bottom surface of the light converting member **41** and reflected by the reflecting portion **45***c*.

The light converting member **41** is provided in the depression portion **49***e* so that the upper surface of the transmitting member **49** and the upper surface of the light converting member **41** are provided flush each other. Therefore, the upper surface of the transmitting member **49** and the upper surface of the light converting member **41** are exposed to the outside, and function as the secondary light emitting portion **43**. Thus, the transmitting member **49** has one part **43***b* of the secondary light emitting portion **43**, and the light converting member **41** has the other part **43***c* of the secondary light emitting portion **43**. The other part **43***c* of the secondary light emitting portion **43** has a circular shape.

The beam spot of the primary light which is emitted from the primary light emitting portion **25** and which illuminates the bottom surface of the light converting member **41** has a circular shape. In this instance, the size of the beam spot is smaller than the bottom surface of the light converting member **41**.

Now, an operation method according to the present embodiment is described.

Some of the secondary light is emitted to the outside from the upper surface of the light converting member **41** (the other part **43***c* of the secondary light emitting portion **43**), and the rest of the secondary light is emitted to the transmitting member **49** from the side surface and the bottom surface of the light converting member **41**. The rest of the secondary light travels toward the reflecting portion **45***c* through the transmitting member **49**, and is reflected by the reflecting portion **45***c* in such a manner as to travel forward. The rest of the secondary light travels toward the upper surface of the transmitting member **49** through the transmitting member **49** without entering the light converting member **41** again. The rest of the secondary light is then emitted to the outside from the upper surface of the transmitting member **49** (one part **43***b* of the secondary light emitting portion **43**).

In general, when the light converting member **41** is a fluorescent material, the light converting member **41** has an absorption property to absorb some of the secondary light (fluorescence) generated in the light converting member **41**, and a scattering property to scatter the rest of the secondary light (fluorescence). In the case of the secondary light according to the present embodiment, a decrease in the amount of the secondary light caused by the absorption property and the scattering property is small. Therefore, the extraction efficiency of the secondary light is high.

In particular, the secondary light is emitted more from the bottom surface of the light converting member **41** than from the side surface of the light converting member **41**. Therefore, most of the secondary light is emitted rearward. The secondary light then travels to the secondary light emitting portion **43** without passing through the fluorescent material because of the reflecting portion **45***c*.

Thus, according to the present embodiment, all the primary light is applied to the bottom surface of the light converting member **41** so that the secondary light can be fully generated by the light converting member **41**. According to the present embodiment, the upper surface of the transmitting member **49** and the upper surface of the light converting member **41** are provided flush each other, are exposed to the outside, and function as the secondary light emitting portion **43**. Therefore, according to the present embodiment, the secondary light can be fully emitted to the outside.

According to the present embodiment, the primary light emitting portion **25** and the bottom surface of the light converting member **41** are provided apart from each other due to the transmitting member **49**. Therefore, according to the present embodiment, the primary light incidents the bottom surface of the light converting member **41** from the primary light emitting portion **25** in an expanded state so that the density of the primary light decreases. Thus, according to the present embodiment, local heat generation can be prevented in the bottom surface of the light converting member **41**, stronger primary light can be applied to the bottom surface, and bright secondary light can be emitted.

According to the present embodiment, the bottom surface of the light converting member **41** has the same shape as the beam spot, and is larger than the beam spot. Therefore, according to the present embodiment, the secondary light emitting portion **43** having a large size can be ensured, and bright secondary light can be emitted.

According to the present embodiment, the transmitting member **49** has an elliptic-cylinder shape. Therefore, according to the present embodiment, a larger secondary light transmitting area and larger secondary light emitting portion **43** can be ensured and brighter secondary light can be emitted than when the transmitting member **49** has a circular-cylinder shape. According to the present embodiment, the secondary light can be surface-emitted to the imaging target even if the distal end face is close to the imaging target.

According to the present embodiment, the gap portion may be provided as long as the primary light emitting portion **25** and the bottom surface of the light converting member **41** are provided apart from each other.

Although one optical fiber **23**, one primary light emitting portion **25**, and one light converting member **41** are provided according to the present embodiment, the present invention is not limited to this. As shown in FIG. **6**D, FIG. **6**E, and FIG. **6**F, the same number of optical fibers **23**, primary light emitting portions **25**, and light converting members **41** may be provided, and have only to be coaxially provided. The light converting members **41** are provided adjacent to one another, apart from one another, and linearly beside one another in the major axis direction of the transmitting member **49**. The same also applies to the optical fibers **23** and the primary light emitting portions **25**. Thus, according to the present embodiment, highly efficient illumination can be maintained, and the light converting unit **40** having a high aspect ratio can be provided.

The present invention is not completely limited to the embodiments described above, and modifications of components can be made at the stage of carrying out the invention without departing from the spirit thereof. Various inventions can be made by properly combining the components disclosed in the embodiments described above.

What is claimed is:

1. A light source device for a tubular observation device, the light source device comprising:

a holding member for holding a light converting member, the holding member being separated from an outer periphery of the tubular observation device, the holding member further having a cavity for at least accommodating the light converting member,

a primary light source unit comprising a primary light emitting portion which emits primary light, and

a light converting unit comprising:

the light converting member which converts the optical properties of the primary light when the primary light is applied thereto and which generates secondary light different from the primary light, and

a secondary light emitting portion disposed on a distal end surface on an emitting side of the light converting unit, the secondary light emitting portion emitting the secondary light generated by the light converting member, the secondary light emitting portion being disposed on a distal end of the holding member inside an outer periphery of the holding member,

wherein in a two-dimensional shape of the secondary light emitting portion projected on a surface perpendicular to an optical axis of the primary light, a length of a minimum width of the two-dimensional shape passing through a center of gravity of the two-dimensional shape is different from a length of a maximum width of the two-dimensional shape passing through the center of gravity.

2. The tubular observation device comprising the light source device according to claim **1**, wherein:

the light converting unit is incorporated in a distal end portion of the tubular observation device together with at least one functional unit,

the holding member and the distal end faces of the at least one functional unit are provided in a layout plane representing a distal end face of the distal end portion, and

at least part of the outline of the holding member is coincident with an edge of the layout plane.

3. The tubular observation device according to claim **2**, wherein the layout plane has a layout possible region representing a region obtained when a region in which the distal end face of the at least one functional unit is disposed is removed from the layout plane,

the secondary light emitting portion is provided in the layout possible region so that the secondary light emitting portion is exposed to the outside, and

at least part of the outline of the holding member is coincident with part of an edge of the layout plane.

4. The tubular observation device according to claim **3**, wherein the distal end face of the at least one functional unit is provided in the layout possible region so that the distal end face is exposed to the outside, and

the layout possible region is surrounded by the edge of the layout plane and an edge of the region in which the distal end faces of the at least one functional unit is disposed.

5. The tubular observation device according to claim **4**, wherein the distal end portion has a circular-cylinder shape, the layout plane has a circular shape, and part of the edge of the layout possible region has an arc shape, and

at least part of the outline of the holding member has a shape that is coincident with part of the edge of the layout possible region.

6. The light source device according to claim **1**, wherein the two-dimensional shape has one rotation symmetry axis, and the rotation symmetry axis is a twofold or more and sixfold or less rotation axis.

7. The light source device according to claim **6**, wherein the two-dimensional shape has at least one of an elliptic shape, a triangular shape, a quadrangular shape, a pentangular shape, hexangular shape, a semicircular shape, and a shape at least partly having an arc or an elliptic arc, and a polygonal shape in which vertexes are formed by curves.

8. The light source device according to claim **1**, further comprising a shape converting unit which converts the shape of the primary light which is emitted from the primary light emitting portion and projected on a bottom surface of the light converting member to correspond to the two-dimensional shape of the secondary light emitting portion.

9. The light source device according to claim **8**, wherein the primary light emitting portion comprises two or more primary light emitting portions functioning as the shape converting unit.

10. The light source device according to claim **9**, wherein the two or more primary light emitting portions are provided beside one another along the maximum width direction.

11. The light source device according to claim **8**, wherein the light converting unit further comprises

a transmitting region which is provided between the primary light emitting portion and the light converting member, and having at least one of a transmitting member and a gap portion to transmit the primary light and the secondary light, and

a reflecting portion which is provided on the lateral sides of the light converting member and the transmitting region and which reflects the primary light and the secondary light,

the transmitting region and the reflecting portion function as the shape converting unit, and

when the inclination angle of the primary light which is emitted from the primary light emitting portion toward the transmitting region and which has an intensity higher than $1/e^2$ of the intensity of the primary light in the optical axis direction of the primary light is a critical intensity emission angle,

in the primary light which travels through the transmitting region at the critical intensity emission angle,

the primary light which travels in at least the minimum width direction travels through the transmitting region so that the primary light travels toward the reflecting portion, reflected by the reflecting portion, and directly illuminates the light converting member, and

the primary light which travels in at least the maximum width direction travels through the transmitting region and then directly illuminates the light converting member.

12. The light source device according to claim **8**, wherein the light converting unit further comprises

a transmitting member which is provided between the primary light emitting portion and the light converting member and which transmits the primary light and the secondary light and which functions as the shape converting unit,

wherein the transmitting member has a first area and a second area, the second area having a different refractive index from a refractive index of the first area in a plane that intersects at right angles with the optical axis of the primary light.

13. The light source device according to claim **12**, wherein the transmitting member has high refractive regions provided along the minimum width direction, and low refractive regions which are provided along the maximum width direction, the low refractive regions having a refractive index lower than the refractive index of the high refractive regions.

14. The light source device according to claim **13**, wherein the high refractive regions comprise two high refractive regions, and the low refractive regions comprise two low refractive regions, and

the two high refractive regions and the two low refractive regions are alternately provided adjacent to one another in the circumferential direction of the transmitting member so that the refractive index changes by stages from the minimum width direction toward the maximum width direction.

15. The light source device according to claim **13**, wherein the refractive index gradually changes from the minimum width direction toward the maximum width direction.

16. The light source device according to claim **8**, wherein the light converting unit further comprises

a transmitting member which is provided between the primary light emitting portion and the light converting member and apart from the primary light emitting portion and which transmits the primary light and the secondary light and which functions as the shape converting unit, and

the transmitting member has a surface which faces the primary light emitting portion and which scatters the primary light in a desired one direction.

17. The light source device according to claim **1**, wherein the light converting unit further comprises

a transmitting member which surrounds the lateral side of the light converting member and which is provided between the primary light emitting portion and the light converting member and which transmits the primary light and the secondary light,

the transmitting member has one part of the secondary light emitting portion, and the light converting member has the other part of the secondary light emitting portion, and

the other part of the secondary light emitting portion has a circular shape.

18. The light source device according to claim **17**, wherein the light converting member comprises two or more light converting members, and the primary light emitting portion comprises a same number of primary light emitting portions as the two or more light converting members.

19. The light source device according to claim **18**, wherein the two or more light converting members are linearly provided beside one another along the maximum width direction.

20. The light source device according to claim **1**, wherein the secondary light emitting portion comprises a distal end face of the light converting member.

21. The light source device according to claim **1**, wherein a shape of a distal end surface of the light converting member is coincident with a shape of the secondary light emitting portion.

22. The light source device according to claim **1**, wherein:

the light converting unit comprises a plurality of light converting members, and

an optical function of each of the plurality of light converting members is substantially the same.

23. The light source device according to claim **1**, wherein:

the light converting unit comprises a plurality of light converting units;

an optical function of each of the plurality of light converting units is substantially the same; and

the secondary light emitting portion of each of the plurality of light converting units is independent from each other.

24. The light source device according to claim **23**, wherein the secondary light emitting portion disposed in one of the plurality of light converting units is disposed symmetrically to the secondary light emitting portion disposed in another of the plurality of light converting units.

25. The light source device according to claim **1**, wherein the secondary light emitting portion has at least one of an elliptic shape, a triangular shape, a quadrangular shape, a pentangular shape, a hexangular shape, a semicircular shape, and a polygonal shape in which vertexes are formed by curves.

26. The light source device according to claim **1**, wherein the primary light source unit further comprises a light guide member for guiding the primary light to the light converting unit.

27. The light source device according to claim **26**, wherein the holding member includes a bore for accommodating the light guide member, the bore being in optical communication with the cavity.

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